CERN

AMBER

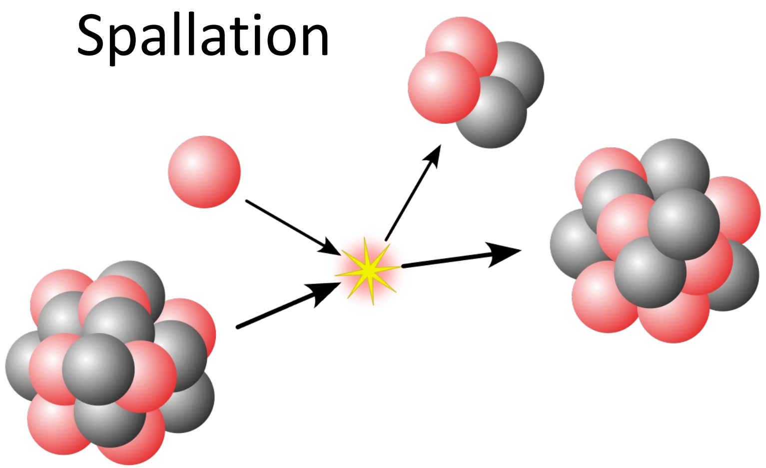
Apparatus for Meson and Baryon Experimental Research

AMBER (CSN1)

P. Zuccon

preCSN2 TIFPA 2023

Introduction



- New accurate measurements have brought Cosmic Rays to a precision era.
- A similar precision is needed in the knowledge of peculiar cross sections is now requested
- Three kind, maybe four, class of problems

  - For all elements: Isotopic Nuclear fragmentation cross sections on ISM (p and He nuclei)
  - Production of pbar and positrons in dominant CR-ISM interactions (p-p and p-He, He-p)
  - Disappearance cross sections of Nuclei on the CR detectors material (mostly C and Al).
  - Cross section for producing anti-nuclei (Dbar, ^{3}Hebar, ^{4}Hebar) in dominant CR-ISM interactions
    (p-p and p-He, He-p)

Introduction

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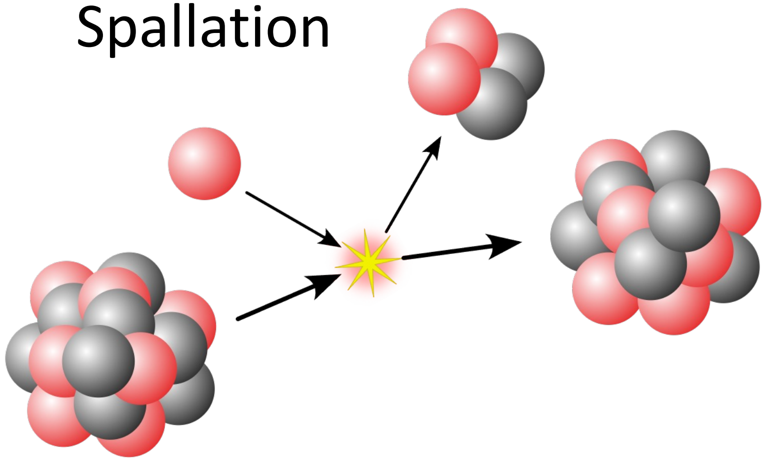
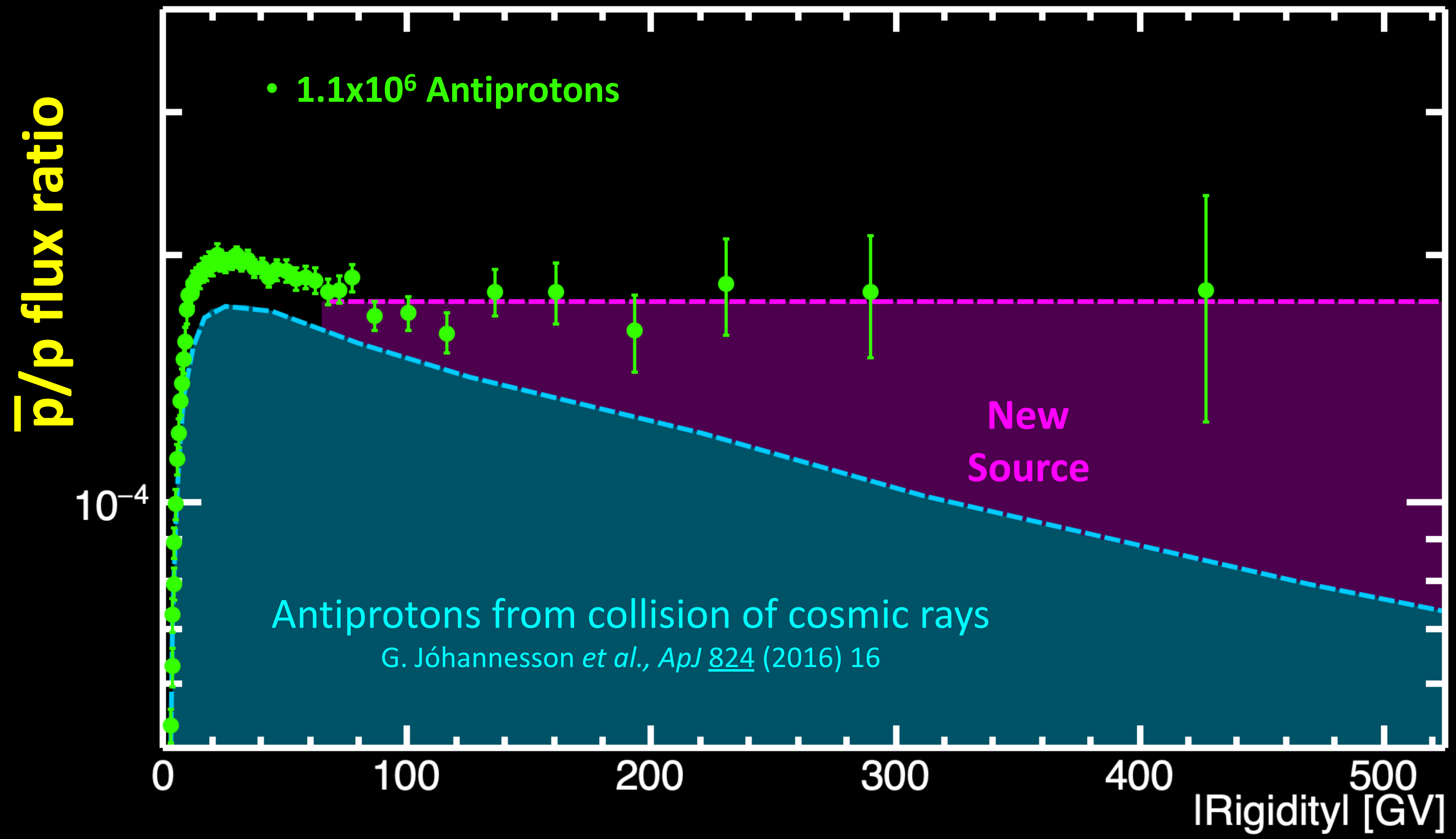


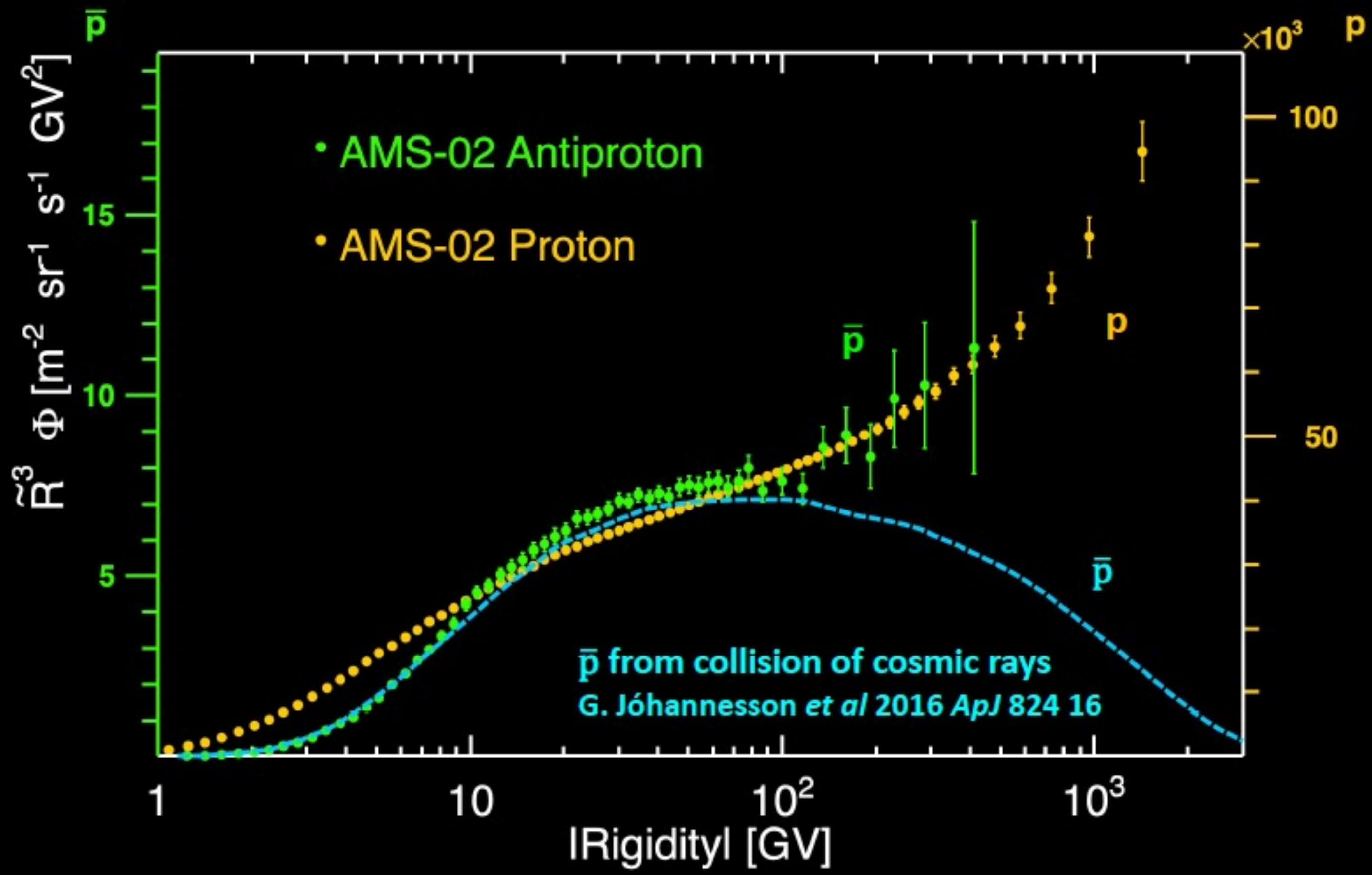
  - For all elements: Isotopic Nuclear fragmentation cross sections on ISM (p and He nuclei) → Solve the "cross-pollination" of CR spectra measured in the Heliosphere
  - Production of pbar and positrons in dominant CR-ISM interactions (p-p and p-He, He-p) → Obtain a better sensitivity to signals from exotic physics
  - Disappearance cross sections of Nuclei on the CR detectors material (mostly C and Al). → Reduce systematic errors on the measurements
  - Cross section for producing anti-nuclei (Dbar, ^{3}Hebar, ^{4}Hebar) in dominant CR-ISM interactions (p-p and p-He, He-p) → Improve sensitivity to primordial anti-matter and to DM

Properties of Cosmic Antiprotons

The antiproton-to-proton flux ratio shows that above 60 GV the ratio is energy independent.



Antiproton and proton spectra



A sample of recent papers on AMS antiproton data

P. Mertsch *et al.*, **Phys. Rev. D 104 (2021) 103029**

M. Boudaud et al., **Phys. Rev. Research 2, 023022 (2020)**

V. Bresci *et al.,* **Mon. Not. R. Astron. Soc., 488 (2019), p. 2068**

M. Korsmeier *et al.,* **Phys. Rev. D 97 (2018), 103019**

P. Lipari, **Phys. Rev. D, 95 (2017), 063009**

I. Cholis *et al.,* **Phys. Rev. D 95(2017), 123007**

M. Winkler, **JCAP, 2017(02), 048**

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Antiproton production and propagation

J. Heisig, **Modern Physics Letters A, (2021), 36, 05**

Y. Genolini *et al.,* **arXiv:2103.04108 (2021)**

I. Cholis *et al.,* **Phys. Rev. D, 99 (2019), 103026**

A. Cuoco *et al.,* **Phys. Rev. D, 99 (2019), 103014**

M. Carena *et al.,* **Phys. Rev. D, 100 (2019), 055002**

A. Reinert *et al.,* **JCAP, 01 (2018), p. 055**

A. Cuoco *et al.,* **Phys. Rev. Lett., 118 (2017), 191102**

M. Cui *et al.,* **Phys. Rev. Lett., 118 (2017), 191101**

Y. Chen *et al.,* **Phys. Rev. D, 93 (2016), p. 015015**

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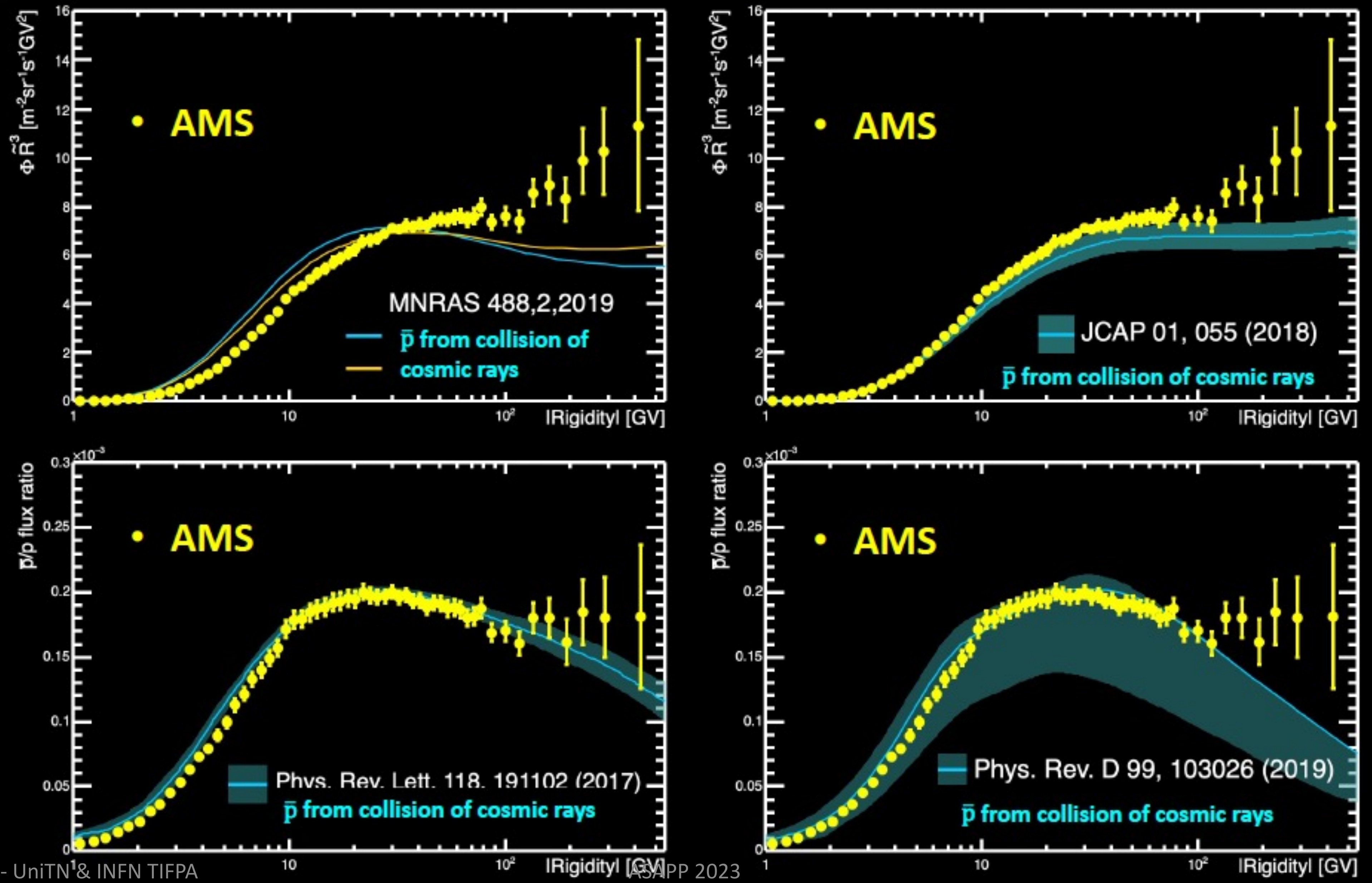
Antiprotons from Dark Matter

Example: AMS Antiproton Results compared with Cosmic Ray Models Based on AMS Data



The AMBER experiment at CERN

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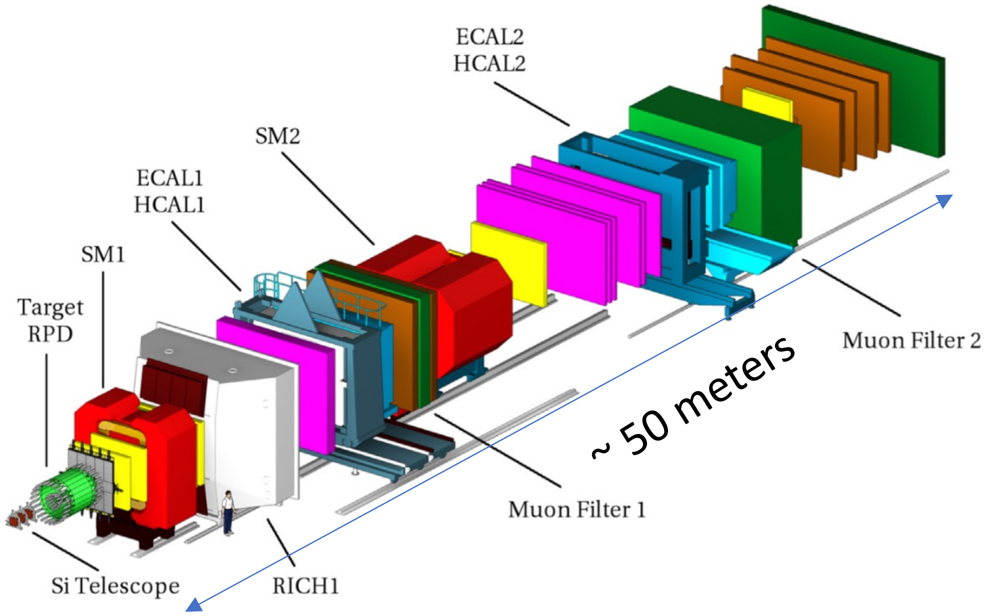
- The AMBER experiment (NA66) is a fixed target experiment at CERN SPS.
- It has been approved for three measurements
  - pbar production cross section in p-He interaction
  - Proton radius measurement though muon-hydrogen scattering
  - Drell Yan processes to study form factors and emergence of the hadron mass
- A proposal for a AMBER phase2 to be done after the LHC long shutdown is in preparation

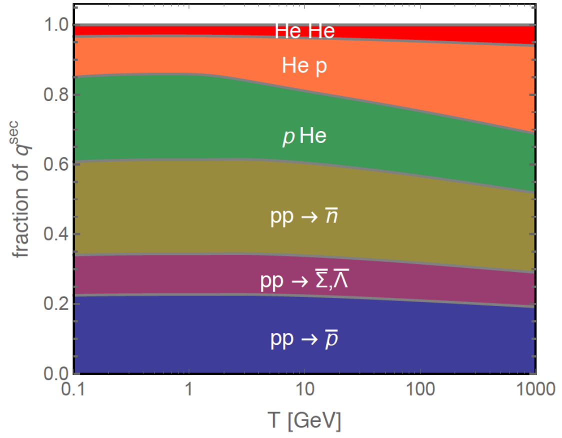


(the AMBER/COMPASS spectrometer)

Existing anti-p cross section

- anti-p production cross section from p-p and p-He interactions is poorly measured and cannot simply constrained from available measurements.
- an accurate prediction of the expected anti-p flux in cosmic rays in the rigidity range from few GeV to several hundreds of GeVs, is interesting to understand cosmic ray and possibly search for signals of new physics
- LHC-b collaboration reported a measurement the anti-p XS from 8 TeV p-He, and foresee a similar measurement with 4TeV protons.
- NA61 published p-p to anti-p at 20, 31, 40, 80, and 158 GeV/c
- we want to investigate the possibility to perform a measurement with the SPS protons between 50 and 280 GeV/c on fixed LH2 and LHe targets, and a magnetic spectrometer

Fraction origin of anti-p from CR interaction with ISM



LHCb-CONF-2017-002
Measurement performed at 7 TeV
p-He -> pbar + X

NA61 p+p data beam momenta of 20, 31, 40, 80, and 158 GeV/c
Eur. Phys. J. C 77, 671 (2017)

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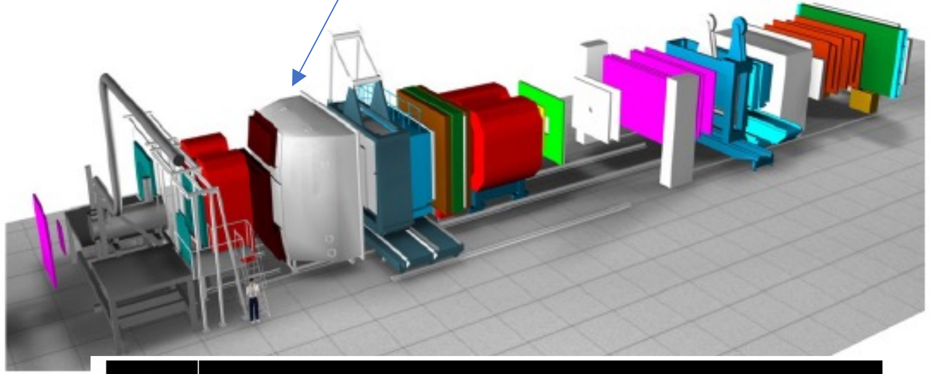
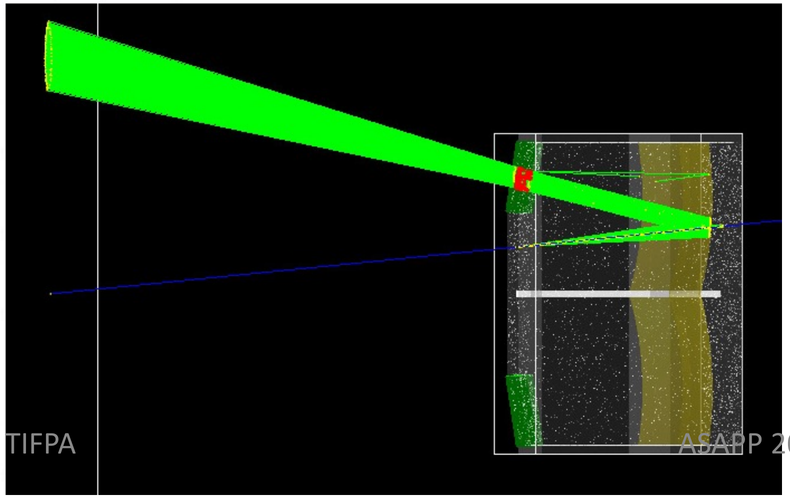
Measuring pbar cross section with AMBER

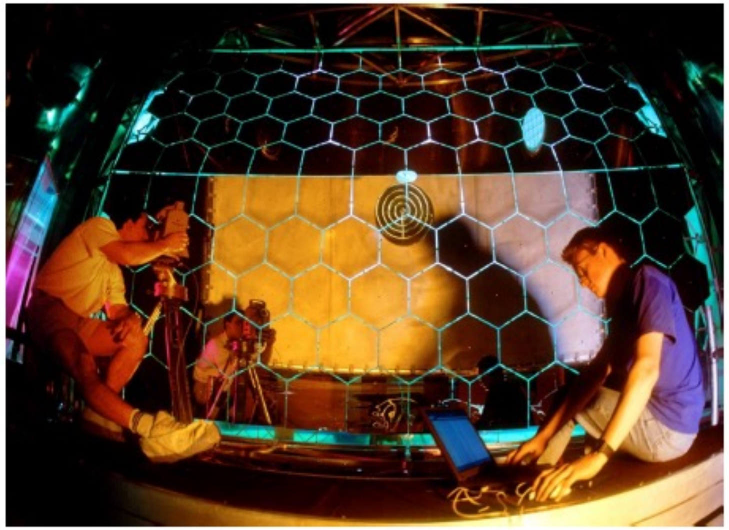
- Target: Liquid ^{4}He cylinder 1.2 m long for 10 cm of diameter
- Precise beam telescope measuring the incoming particle trajectory
- Two stages spectrometer (50m long) with typical momentum resolution ranging from 1% to 0.1%
- Large gas RICH detector for Particle identification
- Use secondary hadron beams from primary SPS proton on a Be target.
- Explore 6 proton momenta: 60, 80, 100, 160, 190, 250 GeV/c
- Use 2 long CEDARs (threshold Cerenkov) to identify protons in the hadron beam

Non Tracking detectors

- Two sets of ECAL and HCAL
- One of the largest RICH detectors ever operated.







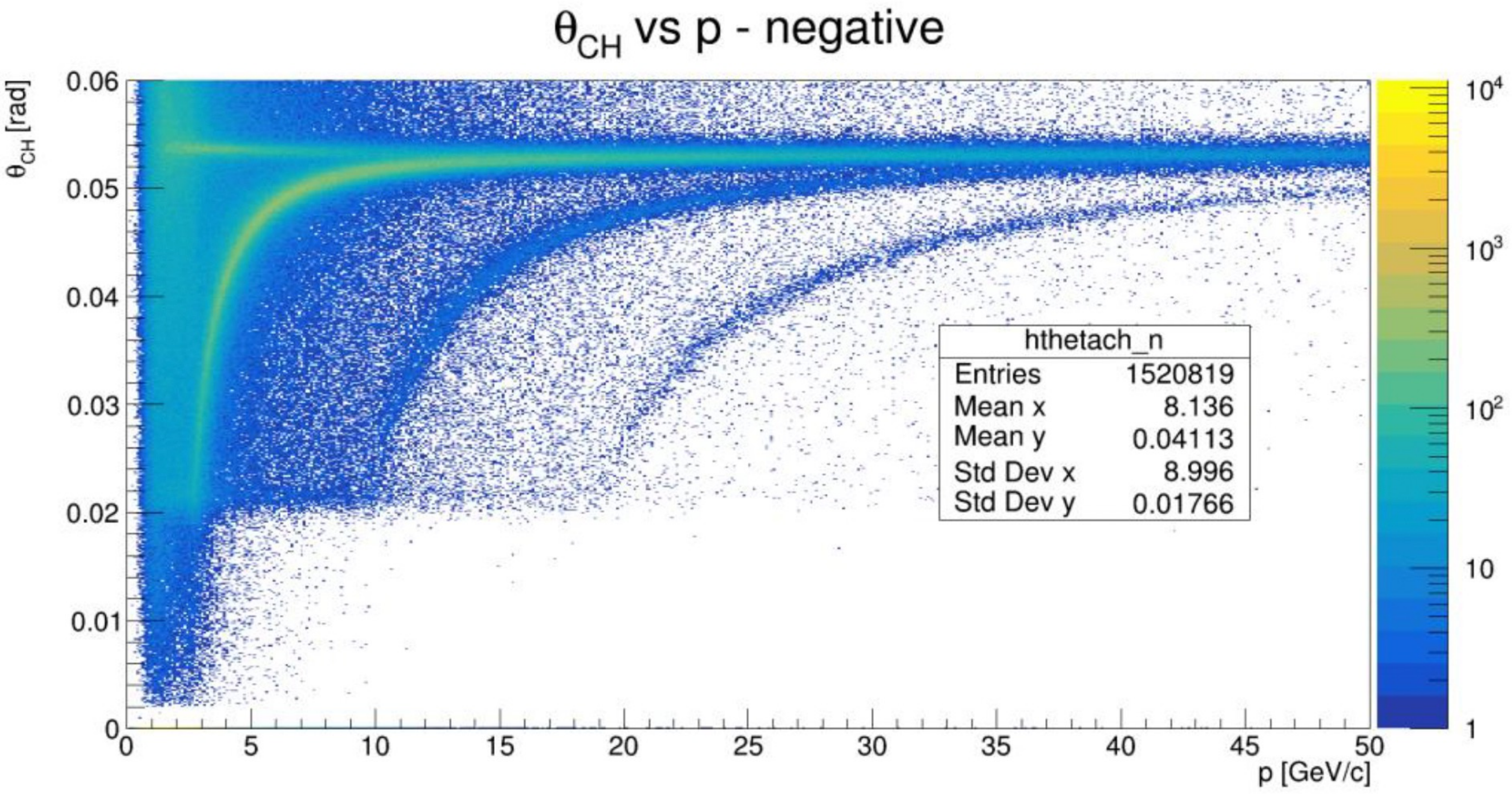
AMBER -2023 Physics run

- April 24th: Detector and beam commissioning starts
- May 20th: Data taking starts with p at 190 GeV/c
- May 25th : switch for the long run with p at 60 GeV/c
- June 6th : Switch to p at 100 GeV/c
- June 11th : switch to 250 GeV/c
- June 14th : switch to 160 GeV/c
- June 18th : switch to 80 GeV/c
- June 25th : Last day with liquid He target
- June 26-28th: Empty target runs
- June 29th-30th: Drell Yan high intensity test
- July 1st : CEDAR PID efficiency runs

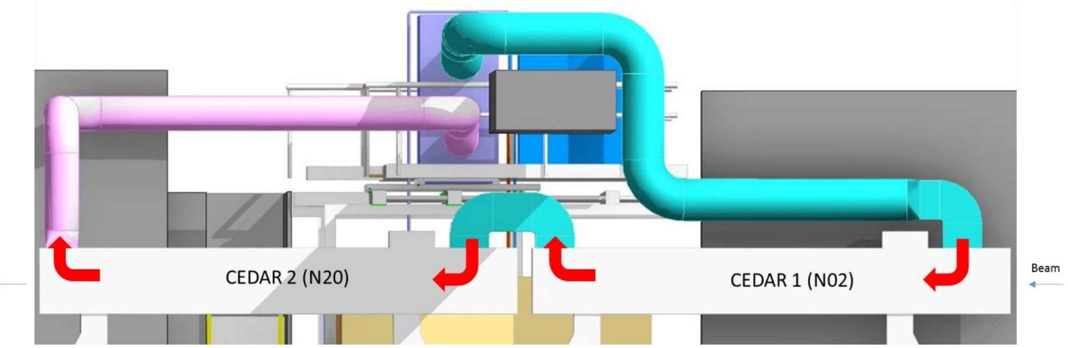
NOTE: SM1 and SM2 currents have been scaled such that the primary beam at different momenta follows the same path within the spectrometer as the 190 GeV one

We added to additional energy points (80 and 160 GeV), because p-p measurements at those energies are available and it is interesting to compare

RICH Measurement example

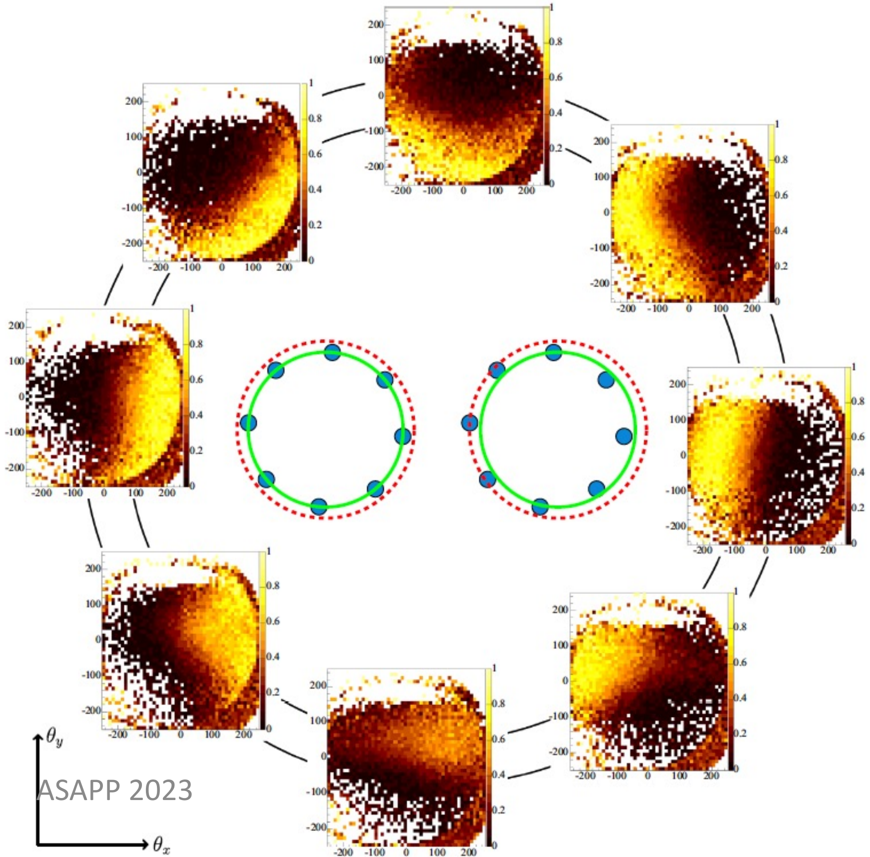


Proton identification in the Secondary hadron beam



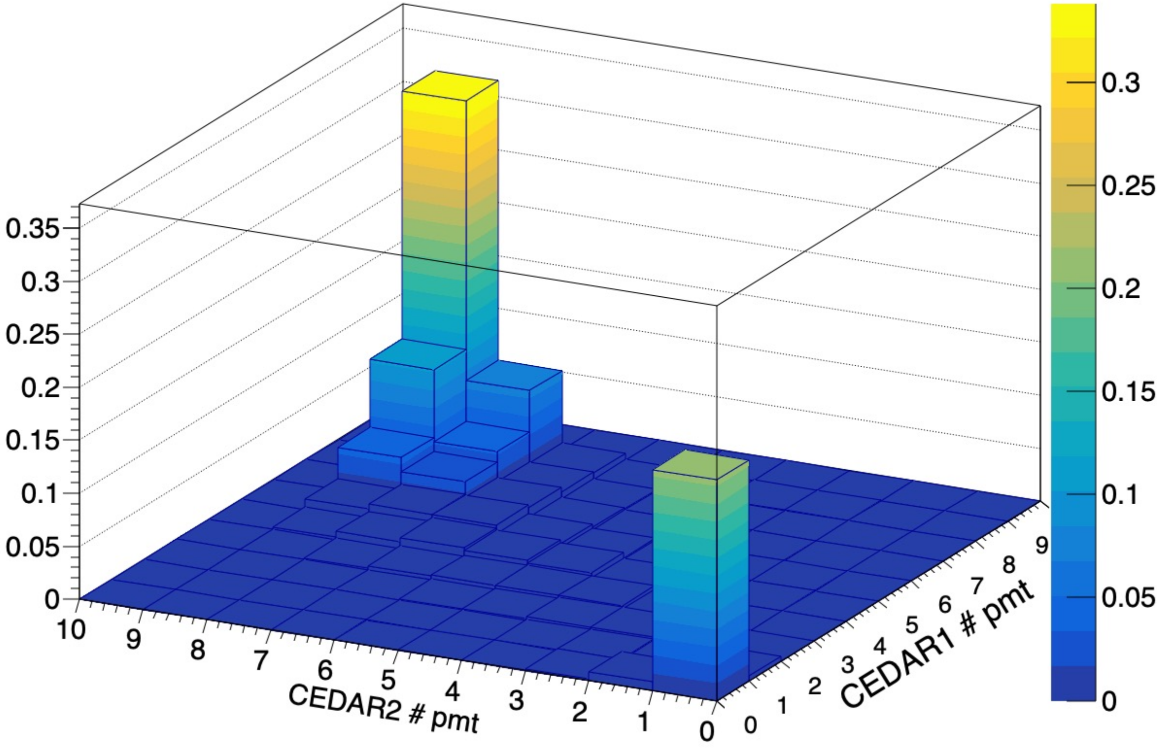
CEDARs

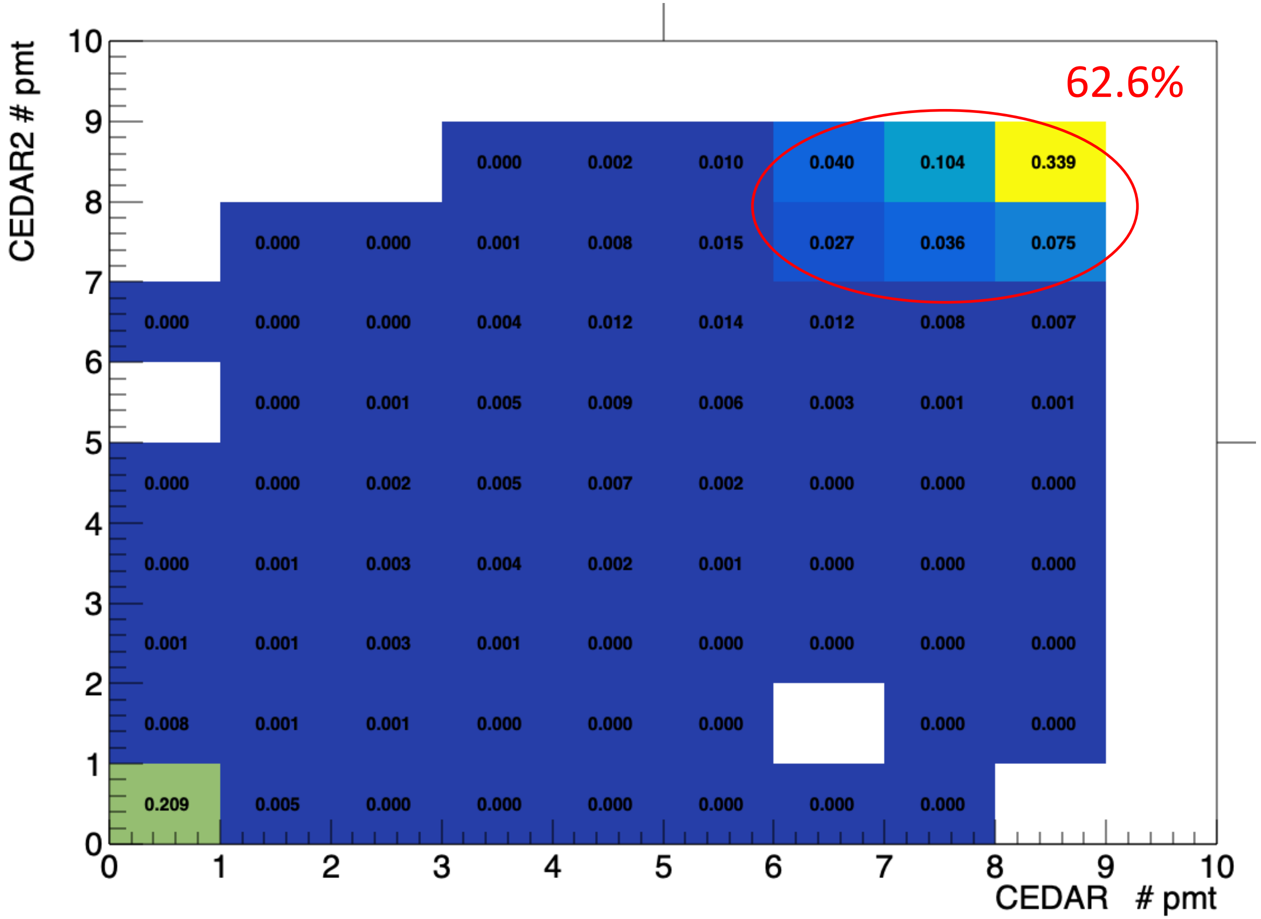
CErenkov **D**ifferential counters with **A**chromatic **R**ing focus



CEDAR Selection p 190 GeV/c

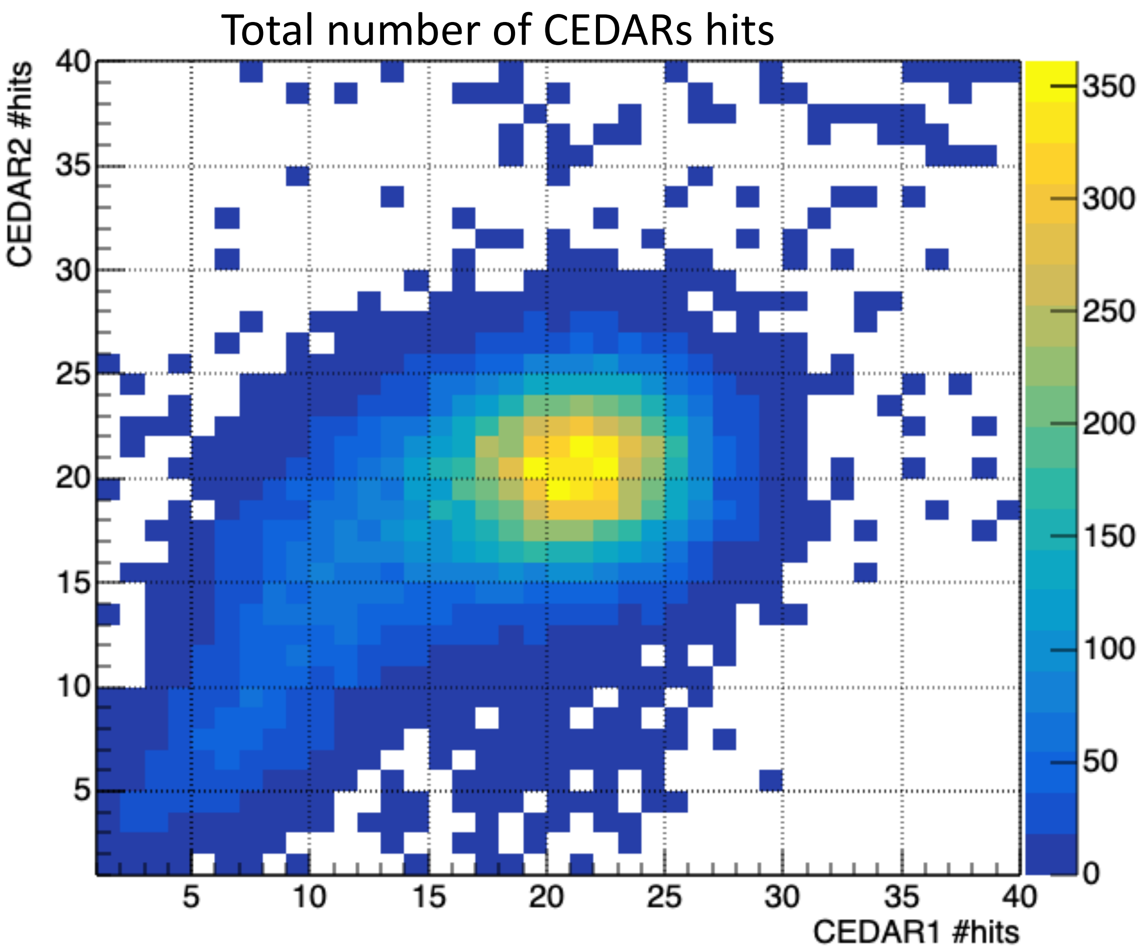
CEDAR1 >= 6 pmts
CEDAR2 >= 7 pmts



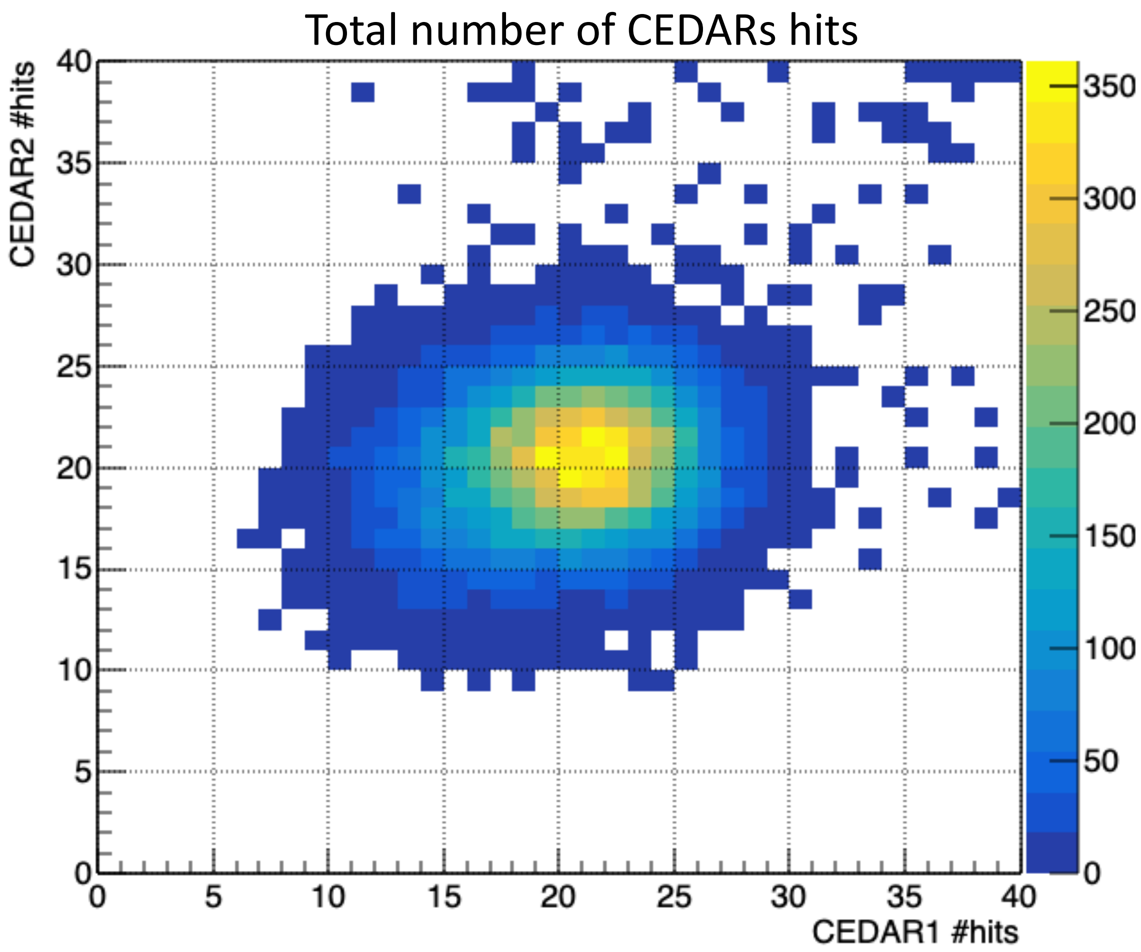


Effect of the CEDAR selection cutt

Before N pmt cut



After N pmt cut



Cross section measurement

- Strategy
  - Count all the p-p (or p-He) interaction in the target (R_i)
  - Identify events with one (or multiple) anti-p vs reconstructed momentum and angle ($R_s\ (p, \theta)$)
  - Calculate the double differential cross section as

$$\frac{d\sigma_{\overline{p}}}{dp\ d\theta} = \frac{R_s(p,\theta)}{R_i}$$

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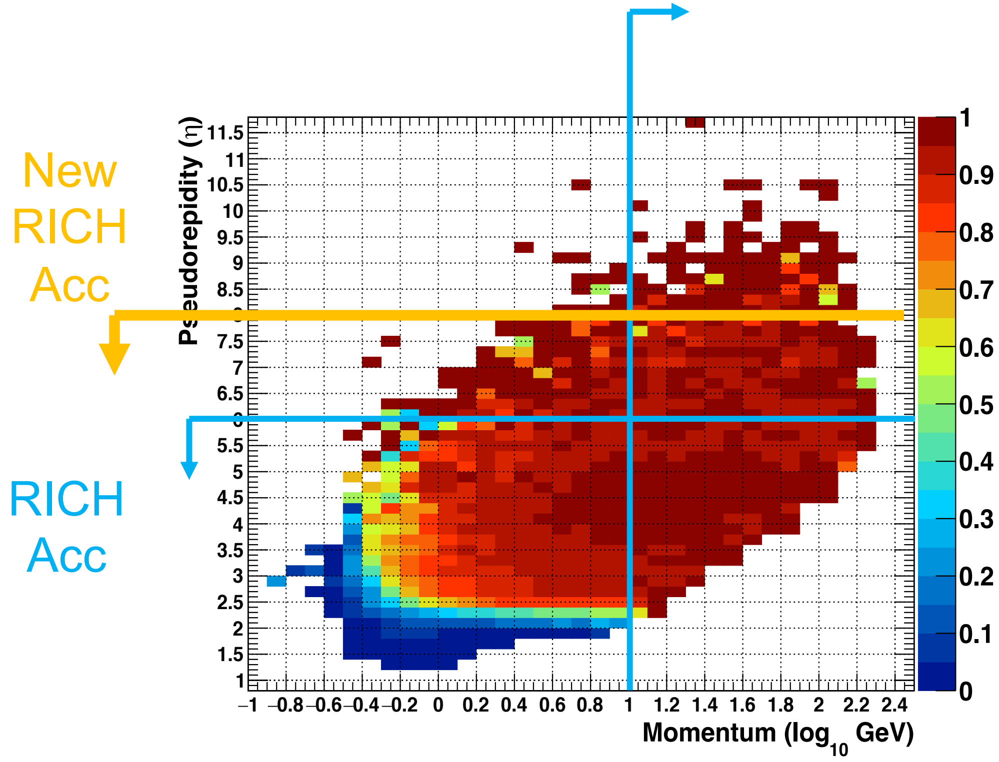
Explored phase space for anti-p production

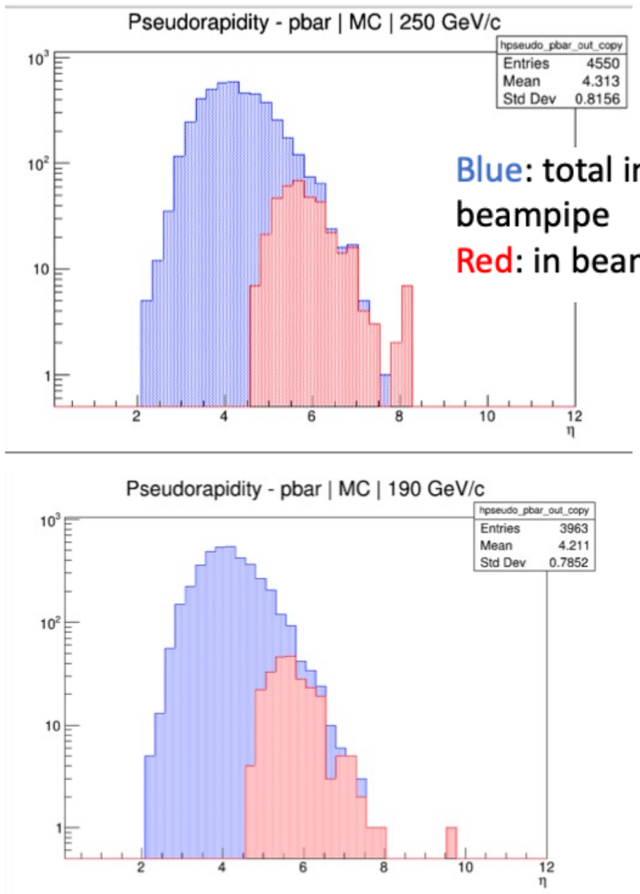
Antiproton tracking efficiency

Pseudo-rapidity vs $\log_{10}$(momentum)

Particle Identification Threshold

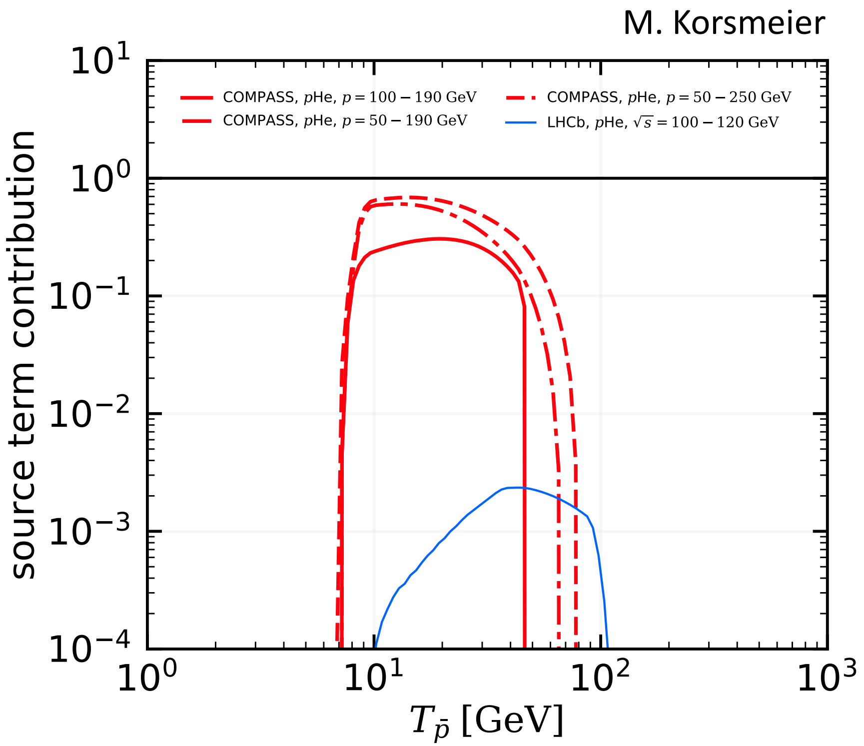


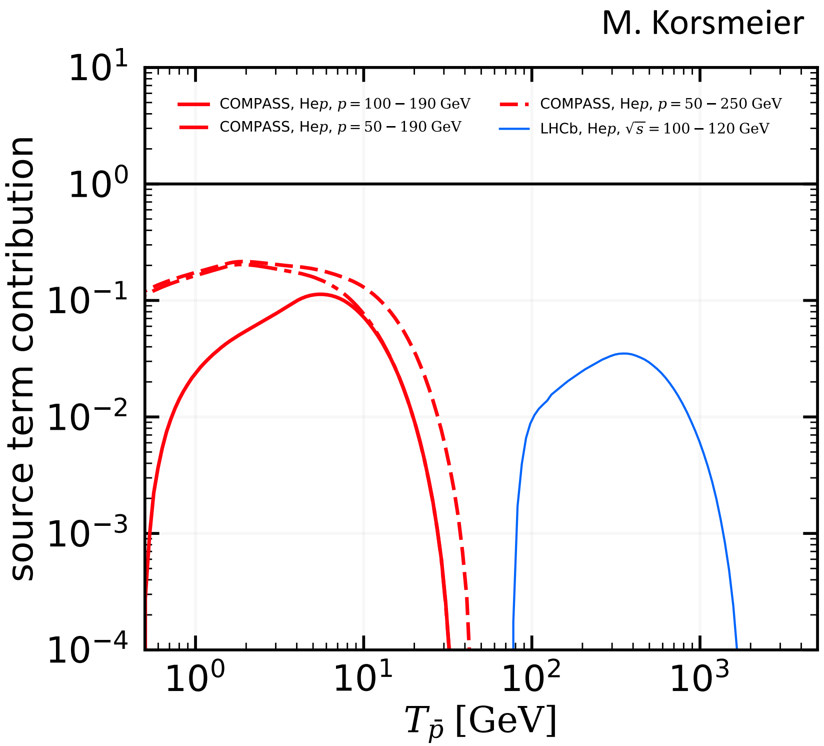
Removal of RICH BeamPipe



Blue: total in+out beampipe
Red: in beam pipe

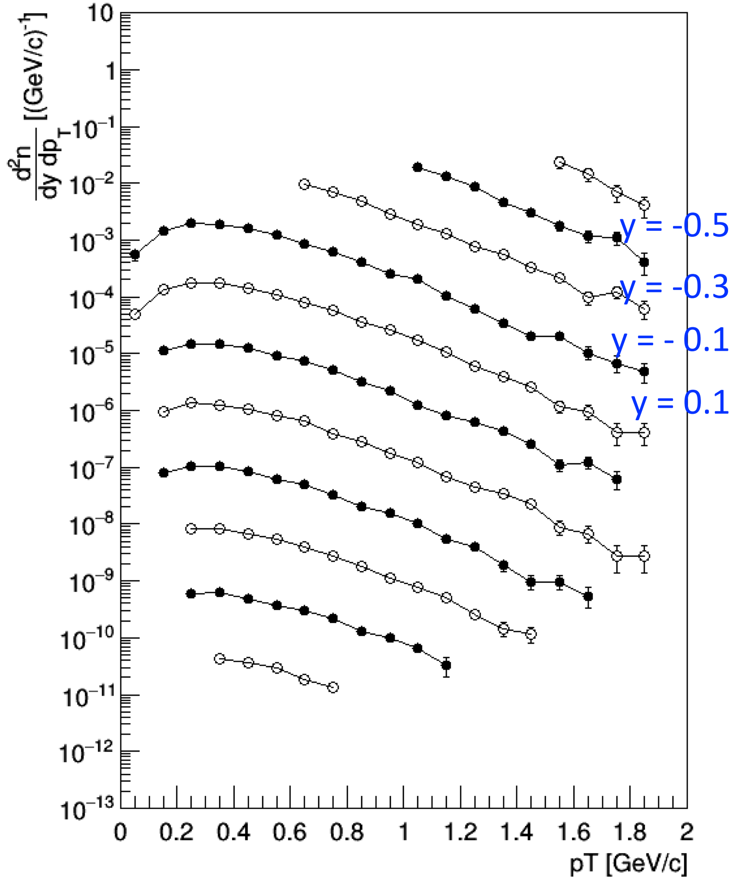
p-He He-p Source term coverage





Expected cross section measurement p-He -> bar-p + X

p 190 GeV/c



Anagrafica

		2023	2024	
Battiston Roberto	PO	0.15	0.15	
Dass Abhinandan	Dottorando	0.5	0.5	
Bisht Ashish	Dottorando	0.15	0	
Gebbia Giuseppe	Assegnista	0.15	0	
Rossi Francesco	Dottorando	0	0.5	
Nicolaidis Riccardo	Dottorando	0.35	0.15	
Nozzoli Francesco	Ricercatore	0.35	0.35	
Zuccon Paolo	PA	0.35	0.35	
TOTALE		**2**	**2**	